Nuclear Energy Risk

Understanding Risk

To properly understand nuclear energy risk first requires a discussion of what is meant by risk, since the understanding of risk, measurements of risk, and even the definition of risk vary in different practice areas. Fundamentally, risk derives from hazards; that is, circumstances with the potential to cause harm. Risk is the likelihood of harm occurring. Since life is full of hazards, life is therefore full of risks, some of which are cognitively recognized, many of which are taken for granted.

Risk may be expressed in a variety of ways. One example, shown in the table below, is the annual probability of death for an individual in the U.S. for specific hazard exposures.

Annual Risk of Death in the U.S.[1]

Hazard	Annual Individual Risk of Death
Heart Disease	1 in 300
Cancer	1 in 600
Motor vehicle accidents	1 in 4,000
Influenza	1 in 5,000
Home accidents	1 in 9,000
Leukemia	1 in 12,500
Falls	1 in 13,000
Drowning	1 in 28,000
Fires	1 in 30,000
Suffocation by ingested objects	1 in 77,000
Air travel	1 in 100,000
Firearms	1 in 100,000
Poisoning by toxic gas or vapor	1 in 135,000
Electrocution	1 in 175,000
Receiving 10 mrem of radiation exposure	1 in 1,000,000
Tornadoes/Hurricanes	1 in 2,000,000
Lightning strike	1 in 2,000,000
Venomous bites and stings	1 in 5,000,000
Radiation release from nuclear power plant	1 in 10,000,000
Meteorite strike	1 in 100,000,000,000

[1] Covello, V.T., Sandman, P.M. and Slovic, P., *Risk Communication, Risk Statistics, and Risk Comparisons: A Manual for Plant Managers*, Appendix B, Chemical Manufacturers Association, Washington, D.C., 1988

Note that it is not always clear what is included in specific risk entries. Most tables of risk comparisons in the literature contain a mixture of risks with only a single risk estimate number having no range or error term. For risks such as driving, where fatalities can be counted, the number is likely to be reliable. But for risks such as radiation or food additives – based not on counting and actuarial statistics but on theoretical modeling and extrapolation – the number is likely to be highly uncertain. Just because a risk statistic is published doesn't mean it's reliable if any assumptions associated with its derivation are not understood.

In addition, tables of risk comparisons are often neither clear nor consistent about the population used to calculate the risk. Within the same table, some risk estimates are based on an entire population (e.g., the United States), while others are based only on the population that is exposed to a particular hazard (e.g., only people who hunt or live in tornado-prone regions).

Finally, risk is mostly a relative quantity, which by itself is rather meaningless. A risk value only makes sense when compared to values from other events, or the same event over a different time interval.

In the safety field risk is typically defined as the likelihood and severity of hazardous events. In mathematical form, this can be expressed as

Risk = Probability of Event Occurrence x Event Consequence Severity

Relative risk magnitudes can be defined for the various combinations of likelihood of hazard occurrence and hazard consequence as illustrated in the following risk matrix.

		Likelihood				
		1 Rare	2 Unlikely	3 Possible	4 Likely	5 Almost Certain
Consequences	5 Catastrophic	5 Moderate	10 High	15 Extreme	20 Extreme	25 Extreme
	4 Major	4 Moderate	8 High	12 High	16 Extreme	20 Extreme
	3 Moderate	3 Low	6 Moderate	9 High	12 High	15 Extreme
	2 Minor	2 Low	4 Moderate	6 Moderate	8 High	10 High
	1 Negligible	1 Low	2 Low	3 Low	4 Moderate	5 Moderate

For quantitative risk assessments, each of the likelihood labels would be defined by a range of hazard frequencies (e.g., probability per year) and

each of the consequence labels would be defined by the severity of the possible hazard outcomes (e.g., death, financial loss, etc.).

Risk Perception

One of the major obstacles to effective risk communication is risk perception – the notion that some risks are "acceptable" and others not. It is the discussion of what should be considered an acceptable level of risk in which emotional passions may run high.

Risk perception is generally driven more by the magnitude of the potential consequences than by event likelihood of occurrence. The potentially severe consequences associated with some risks are oftentimes dissociated from their extremely low likelihoods of occurrence in the minds of the public. Furthermore, risks associated with complex technologies like nuclear power are perceived by the public to be much higher than warranted.

Risk Models

There are two kinds of risk models – one model is based largely on theoretical risk using inference and extrapolation, while the other is based on actual risk observations.

A fundamentally sound risk model should render a risk hierarchy based on logical, analytical thinking, mitigation strategies focused on identifying root causes, and mitigating action decision-making driven by informed and knowledgeable experts.

Unfortunately, what we often get are risk hierarchies based on emotion-laden perceptions of risk, mitigation strategies focused on agenda-driven symptoms, and decision-making mandated by ideology. Such a risk model will likely result in either no risk mitigation or an unacknowledged transfer of risk to another setting.

Quantification of Risk

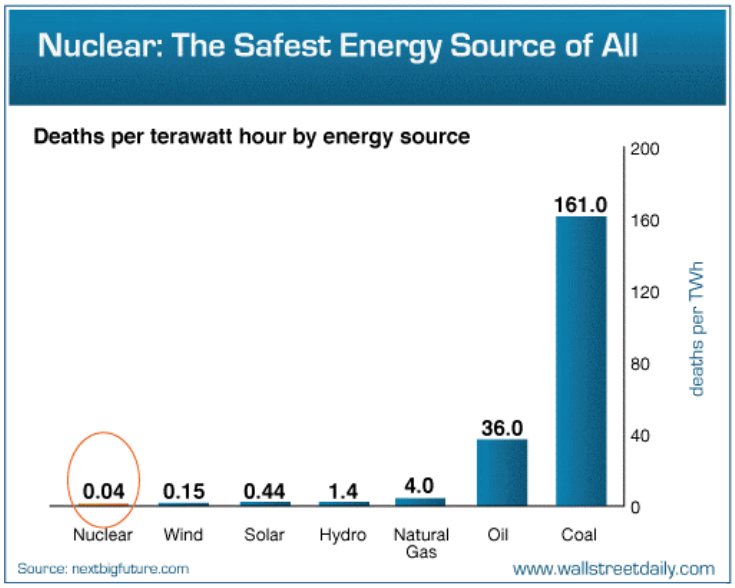
Quantification of risk is generally necessary for informed risk decision-making and necessarily involves quantifying the value of human life. To paraphrase S.M. Barrager,[2] while some might see the quantifying of human life as callous, it is important to observe that the intent is not to value a human life or injury in a moral sense, but rather to assign values to life and other loss categories as a means for making social decisions. The values are not measurements, but the results of a decision made by society concerning the balancing of social benefit and social risk. Thus, the problem is to assign a value to human life that reflects what society is willing to pay to avoid a death from involuntary risk.

[2] S.M. Barrager, et al, Decision Analysis Dept., SRI International, "The Economic and Social Costs of Coal and Nuclear Electric Generation," 1976

If the value of life is not quantified, resources (also having value) cannot be allocated rationally to develop and implement risk countermeasures to protect life. Furthermore, if all life is given infinite value, no distinction can be made between resources justified to protect 10 lives and those justified to protect 10 million.

Nuclear Power Plant Risk

The safety of nuclear power is unmatched by any other energy resource as shown in the figure below. Yet, despite its safety record the perception of nuclear power as uniquely dangerous endures. This is reflected in the regulatory burden placed on the nuclear industry, which is geared towards an “as low as possible” approach, demanding radiation exposure levels to be extremely far below the levels where health effects can first be observed, in some cases below even natural background radiation. To fully unlock the potential of the atom, it is crucial that the gap between perceived and actual risks is addressed. Policymakers and regulators must ensure that their decisions regarding nuclear power plant risks do not create greater risks elsewhere. This includes the recalibration of existing regulations regarding nuclear power and radiation, weighing the cost of regulatory measures against the societal benefits provided by nuclear energy.



NPP PRA

Nuclear Power Plant probabilistic risk assessments (PRA) are performed to provide systematic assessments of public risk associated with the operation of commercial nuclear power reactors. PRA analysts use event trees and fault trees to identify and analyze initiating events, safety function performance, and accident sequences to assess the frequency and consequences of not achieving a safe, stable accident outcome.

Frequency of occurrence and failure probability estimates come from operating experience (frequency of initiating events, failure rates of plant equipment, equipment repair and recovery probabilities), expert elicitation for rare events, human reliability analysis, and common cause failure modeling.

PRA outputs include estimates of reactor core damage frequency, radiological release frequencies, and radiological consequences to the public. However, PRAs use probabilistic risk models developed from reactor safety studies, which assume conservatively high radioactive material releases under severe accident conditions and apply the linear no-threshold (LNT) dose-response and collective-dose models for predicting cancer risk fatalities. The flawed nature of the LNT model has been extensively addressed by Dr. Edward Calabrese and use of the collective-dose model for predicting radiation-induced fatalities has been rejected by the American Health Physics Society. Use of these models in nuclear plant PRAs immediately calls into question the realism of PRA risks.

Assessment of NPP PRA Realism

Based on observations of the Three Mile Island and Fukushima nuclear plant accidents,

- the observed probability of occurrence of some accidents is greater than assumed in plant PRAs, and
- accident radiological consequences are over-estimated (i.e., latent radiation-induced cancers are over-estimated relative to actual observations – the LNT problem).

In addition, the consequences of unwarranted public evacuations are more damaging to public health than a realistic radiation release from a reactor core melt accident.

These observations led to the Nuclear Regulatory Commission State-of-the-Art Consequence Analyses,[3] published in 2012, which concluded that

- Latent cancer fatality risk from nuclear plant accidents is “millions of times lower than the general cancer fatality risk in the United States from all cancer causes, even assuming the LNT dose-response model.”
- Unrealistic estimations of public health consequences have driven many complex regulations for nuclear power plants to prevent very unlikely events that could release less than harmful amounts of radioactive material.

Risk Calculation Cautions

Risk probability calculations, although necessary for performing bona fide risk assessments, must not be afforded absolute status. Low probability events do occur despite best efforts to minimize their likelihood of

[3] State-of-the-Art Reactor Consequence Analyses, NUREG-1935, November 2012

occurrence. Just because an event has an extremely low probability or frequency, it can still happen today, tomorrow, or next week. In fact, it can occur today, *and* tomorrow, *and* next week. It is not likely, but neither are any other unlikely catastrophes that strike without any apparent schedule (e.g., earthquakes, floods, tsunamis, etc.).

Risk Acceptability
Determining what constitutes an "acceptable" level of risk will seldom be without controversy, and will vary depending on one's perspective regarding the risk under discussion. So, the question is, what level of risk should a nuclear power plant be designed for?

The answer to that question requires answers to the following additional questions.

- What level of risk is society willing to accept to assure a supply of abundant and reliable electricity?
- What cost is society willing to incur to guarantee only "tolerable" nuclear power plant damage from any conceivable risk (e.g., a meteor strike)?

If society is unwilling to accept very low probability risks, or bear the increased costs associated with bringing all conceivable risks into a nuclear power plant's design basis, then abundant and reliable electricity may, at some point, become an historical artifact.

Consequences of Over-Regulation
The overly complex regulations for nuclear energy facilities driven by the LNT and collective-dose models have hugely increased the costs of facility construction and operation and denied the American public a clean, safe, and reliable source of electricity.

Nuclear Risk Communication
Generally, no distinction is made between theoretical risk and real risk when communicating risk matters to the public. The potential consequences of theoretical risks are generally modeled and are heavily dependent on assumptions underlying the risk model. The actual consequences of real risks can be measured.

Risk communications can be unnecessarily complicated by the media, which is often guilty of communicating unwarranted dire speculations and outright falsehoods about an event before the facts are available. Once an anti-nuclear risk narrative has been established by the media, it's extremely difficult to counteract such a narrative when factual information becomes available, especially when those being held responsible for the event are also alleged to be incompetent or involved in a criminal coverup by the biased media (as tends to happen with all things nuclear).

Following the communication failures during the 1979 Three Mile Island accident, Peter Sandman and Vincent Covello began writing about how to effectively communicate risk to the public. The issue of nuclear risk communication has been a topic of discussion since the 1980s and seemingly has not made any headway in the past 30+ years. Why is that? I believe it's because of media bias and the fact that people would rather be frightened of things they don't understand. Beliefs tend to be driven by emotions, and when it comes to communicating nuclear risk matters to the public via the media, the media is anything but objective.

With respect to nuclear power industry risk communications, one can speculate that either the industry has failed to effectively implement the Sandman/Covello risk communication recommendations or the recommendations didn't work. I suspect it was the latter that brought the industry to where it is today. I believe that underlying the risk communication recommendations is an implicit assumption that the "audience" for which the communication is intended consists of rational people capable of critical thinking. We know that antinuclear people are not rational, and that most Americans have never been taught how to think critically about anything. Often the public merely parrots what they have been told is true and are reluctant to admit that their beliefs may, in fact, be incorrect.